PIONEER REPORTS OF PLANT BACTERIAL DISEASES

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"Those who ignore history are condemned to repeat it"

Author Notes

1. The objective of this paper is not to indicate who was the first to report a plant bacterial disease in the world, the intention in to present to the plant pathology community some points drawn from the pioneer's papers of Plant Bacteriology for academic discussions.
2. This article was originally published in Portuguese in the periodical RAPP (2009) following to the editorial board regulation of that proceeding. Now this issue is presented in English with the objective to promote a worldwide circulation and better understanding of the international scientific community.

RESUMO

TRABALHOS PIONEIROS SOBRE DOENÇAS BACTERIANAS DE PLANTAS

Foram pesquisados antigos documentos do histórico da Fitobacteriologia e apresentados relevantes dados do que pode ter sido o real primeiro assinalamento de uma doença de planta causada por bactéria. Sobre E. F. Smith, proclamado "Pai da Bacteriologia de Plantas", alguns dos seus pioneiros estudos sobre fitobacterioses foram comentados, sobretudo o seu envolvimento com a histórica polêmica movida naquela época sobre bactérias como organismos causadores de doenças em plantas.

Termos para indexação: história da patologia de planta, fitopatologia, doenças de plantas.

ABSTRACT

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It was researched historical pioneer papers and presented relevant data about what could have been the real first report on a plant disease caused by a bacterium. On E.F. Smith, proclaimed "The father of the Plant Bacteriology" some of his pioneer papers were commented and above all his involvement with the historic polemic on the bacteria as agent of plant diseases.

Index terms: history of plant pathology, phytopathology, plant diseases.

Overview

There is an open question and controversies in the History of the Plant Pathology concerning who was the first to report a plant disease caused by a bacterium. In Brazil, the older plant disease investigators such as Puttmans (1936) in Rio de Janeiro, Costa (1975) in São Paulo e Dantas (1970) in Pernambuco, among others, gave the credit to the German scientist F. M Draenert, considering his paper written in Jena, Germany, about his discovery in the State of Bahia, Brazil. Draenert's article came out after his scientific investigations on an unknown sugarcane disease, later nominated gummosis, in the State of Bahia (Draenert, 1869). This article was republished twice in Brazil; initially in Salvador, Bahia (Jornal da Bahia, 1870) and later in Recife, Pernambuco, in the Anais da Academia Pernambucana de Ciência Agronômica (Moura, 2006). On the other hand, worldwide scientists believe that the North–American plant pathologist T. J. Burrill must receive the credit due to his original researches and the two publications on the etiology of pear and apple blight (Burril, 1877; 1878). One particular aspect of this issue should be taken into consideration. Since these investigations were developed before the establishment of the pure culture methods and the new concepts on etiology as well as Koch's rules of proof, one can justifiably ask if those memorable pioneer articles presented evidence or proof that the bacteria were the cause of the two diseases. Kennedy *et al.*, 1979 presented an excellent short review under the title: Bacteria as the cause of disease in plants: a historical perspective. According to these authors, at least three investigators should be considered in the historical concept of bacteria as plant pathogens. According to those authors, Thimann (1963) in his treatise: The Life of Bacteria, gave credit to E. Mitscherlich (1850) a German chemist, to be the first to discover e report that bacteria could cause a plant disease. The discovery was reported to the Imperial Academy of Science in Berlin at that year. Mitscherlich published his observations on an "active liquid" that degraded potato–tuber cell walls, most certainly the disease actually known as soft–rot of potato. He reported

additional data such as the content of cellulose in tuber cells and described the progressive degradation of slices of potato tuber in the presence of the bacteria. He attributed this action to *Vibrios* (*Vibrios* was one of the six genera of bacteria at that time) and affirmed that no trace of fungi could be found in the decaying tissues. Mitscherlich did not produce further works on this topic and his discovery was neglected in the following similar publications by the others investigators. It is important to recall that the Europeans biologists in that time peremptorily rejected the idea that bacteria could cause plant diseases, supporting de Bary's concepts. (A. de Bary may be considered as the Father of Plant Pathology due to his pioneering discovery on plant diseases in the XIX Century). The other two investigators and their publications mentioned by Kennedy *et al.*, 1979, were: T. J Burrill, above mentioned and J. C. Arthur, in that time a young investigator that soon became a respectable bacteriologist and responsible for several publications and statements, some of then strongly supporting Burrill's discovery on the etiology of pear and apple blight. Draenert's publication (1869) was not commented nor included in the list of references presented by Kennedy and co–authors in 1979.

Sugarcane is subject to more than one bacterial disease, but that known as gumming diseases or gummosis is the most serious and perhaps the most important disease affecting this plant (Dowson, 1949). It is to be found in nearly all countries where sugarcane is grown on a large scale. The disease is of the vascular type and highly severe on susceptible varieties. According to Puttmans (1936), (A. Puttmans born in Belgium and a naturalized Brazilian) one of the most prominent scientist in the History of Brazilian Phytopathology, in 1836, the German botanic and naturalist Frederic Murices Draenert (Figure 1) came to Brazil to study sugarcane problems in the northeastern region of the country and settled down on a sugarcane farm in Bahia State, Brazil. There, he found what he classified as a devastating sugarcane disease which he immediately got involved with. Later, after his studies and investigations, he reported the disease as caused by "plant cells" (Draenert, 1869), certainly a plant bacteria. At that time the bacteria were considered plants. In Draenert's paper it was said that a similar disease was simultaneously occurring in Cuba, Santa Catarina and Rio de Janeiro, these last two locations are Brazilian States. According to his information, in Rio de Janeiro, the losses were so high that sugarcane plantations were replaced by coffee in some areas (Draenert, 1869). After the investigations Draenert published his conclusions in the periodical *Zeitschrift für Parasitenkunde* (Journal of Parasitology), in Jena, Germany, in 1869, seven years before Koch´s

demonstration of the bacterial etiology of anthrax in animals (the first final proof of the causal relation of anthrax bacillus to anthrax disease was published by H. H. R. Koch in Germany, 1876). In Draenert's paper the word bacteria was not mentioned and the article had as title: *Weitere Notizen über Krankheit des Zuckerrohrs* (Other News on Sugarcane Diseases). This paper was reprinted in Portuguese language in the *Jornal da Bahia* (1870), a commercial newspaper, n° 4935, month of January (Figure 2) under the title: *Molestia da Canna de Assucar na Bahia* (Disease of Sucarcane in Bahia). This article was reprinted *ipsis litteris* by R.M. Moura in the *Anais da Academia Pernambucana de Ciência Agronômica* in 2006 (Draenert, 2006).

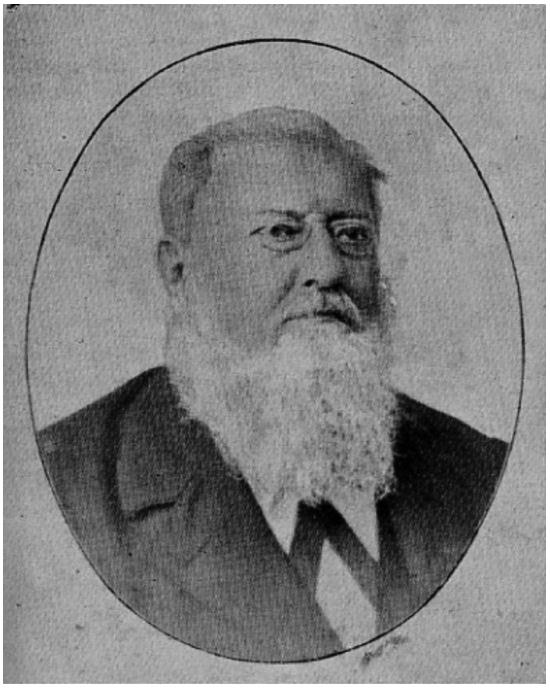

Figure 1. — Frederic Murices Draenert, a German botanic, considered by the majority of the Brazilian plant pathologists the first to report a plant bacteria disease in the world (Courtesy of the Journal Rodriguesia).

It is important to stress that Draenert's publication was printed almost ten years before the two famous T. J. Burrill's paper (Burrill, 1977; 1878), considered by the majority of plant pathologists in the world the milestone of the Plant Bacteriology. In his paper, Draenert initially described the symptoms of the disease and it is extremely interesting to stress that most details he presented, were similar to those induced by the actually well known sugarcane gummosis. He reported the reddish

JORNAL DA BAHIA

MOLESTIA DA CANNA DE ASSUCAR NA BAHIA.

(Traduzido de uma memoria do Sr. F. M. Droinert, publicada no *Zeitschriff fur Pa asiten Kemd.*)

Lê-se no *European Mail for Brazil and the River Plate* o seguinte:

A canna de assucar de alguns annos para cá tem sido affectada, no Brazil, de uma molestia á que se tem attribuido as causas as mais contradictorias, sem que se lhe tenha podido descobrir remedio algum. Fortes queixas tem apparecido tambem, em Cuba, sobre o mesmo objecto, e na provincia de S. Catharina esta cultura foi abandonada em diversos logares. Von Tschudi avizou os colonos do sul do Brazil sobre o mesmo objecto, declarando que elle considerava o clima inteiramente contrario á semelhante cultura, por quanto, segundo as observações feitas de agosto de 1867 á julho de 1868, a temperatura media tinha sido de 70° 7.° Fahrineit, quando a canna de assucar precisa de uma temperatura de 75° 2.° Fart.

Não era possivel esperar que uma planta ão succulenta, podesse, sem prejuiso do eu desenvolvimento organico, estar exosta á uma temperatura de 3°° 2° Fart, omo succedeo em 23 de agosto de 1868, a colonia de Blumenau; o que, na realiade, se observa muitas vezes na estação huvosa. A cultura da canna de assucar, ntretanto, ainda continua n'aquella proincia, e julgam-na proveitosa; em quanto elo contrario na provincia do Rio de Jaeiro, mais ao norte, e mais quente, bem mo nos districtos visinhos, prefere-se a café.

Figure 2. — *Jornal da Bahia* (Bahia Newspaper), N° 4935, January, 1870, reprinted F.M. Draenert's paper (1869), published in Jena, Germany.

of internal tissues, yellowing of leaves and top–rot. No leaf–strip symptoms were mentioned. Along his investigations, Draenert carefully eliminated the possibility of an insect parasite be the causal agent, as it was believed by scientists in that time. In fact, in relation to insect parasitism, he mentioned that the galleries caused by sugarcane bores anticipate the internal reddish of tissues due to air penetration what was followed by oxidations. He make clear, however, that this fact was not related to the disease. Plants affect by these types of symptoms had normal juice, he said. Draenert main found, indeed, was a dense yellow substance associated to infected internal tissues; composed by very small cells he called "plant cells", as mentioned before. He also reported a second type of cells, much lager, most probably conidia of a fungus that could be *Colletotrichum falcatum*, causal agent of the red–rot disease or *Fusarium moniliforme* responsible for the *pokkah–boeng* (top–deformation), both endemic and rarely epidemic sugarcane diseases in that region, even in our days. Puttmans (1936) believed that in some cases Draenert found one of these fungi associated to the gummosis. He supported his seeing describing that Draenert using

a primitive method of isolation, a sugar solution, obtained an organism associated to the disease that he called "a beautiful mushroom oidium". On the other hand, he kept some of the yellow substance in a small glass container with the sugar solution and later observed that it turned into a white dust, composed by the same type of cells observed in naturally infected tissues. These cells were arranged in groups or filaments, similar to those observed in infected internal tissues. Draenert pointed out that this white dust could easily be spread by insects and winds and that the wrong practice of planting infect cutting resulted in diseased plants. In today taxonomic descriptions the etiologic agent of the sugarcane gummosis is primarily characterized by the authors as a bacteria produceing of a yellow stick substance or gum (Dowson, 1949). Draenert clearly indicated the negative influence of the bacterial disease in the milling and sugar production and as final conclusion he stated: …*so, by many reasons this cellular plant should be considered the causal agent of the disease*. The organism observed by Draenert forming the yellow substance was initially identified by Nathan A. Cobb as *Bacterium vasculorum* N.A Cobb (curiosity: Cobb was later proclaimed *The Father of Plant Nematology* due to his outstanding contributions to the science of Nematology). This bacteria was later reclassified by E. F. Smith as *Pseudomonas vasculorum* (N.A. Cobb) E.F. Smith and finally Dowson reported the new combination: *Xanthomonas vasculorum* (N.A. Cobb) Dowson. Today this bacterium is referred as *Xathomonas axonopodis* pv. *vasculorum*. The given name for the disease was "sugarcane gummosis" due to exudates drops of gum from the openings of infected canes. No information was found about who created this disease nomination. So far, sugarcane gummosis has been reported over 25 different countries and became endemic in Brazil due to the use of resistant varieties (Caminha Filho, 1936). For several decades the gummosis was epidemic in Pernambuco State, at that time the main sugar producing state in Brazil. The history of sugarcane gummosis in Pernambuco and Brazil was written by Dantas (1970) and no economic losses caused by the disease have been reported in Brazil in the last decades (Tokeshi & Rago, 2005).

Not much information is available on Draenert's life or on his stay in Brazil. Puttmans (1936) mentioned an unidentified biographer reporting Draenert as an unhappy person who suffered in life deep injustices but with recognized scientific competence.

Water J. Dowson professor of Mycology and Bacteriology at Cambridge University, and former plant pathologist of the Department of Agriculture in Tasmania, both in the United Kingdom, was one of the most respected plant

bacteriologist in the History of Plant Pathology. He had many contacts with the sugarcane gummosis in British's sugarcane producing areas and was responsible for the second classification of the etiologic agent: *Xanthomonas vasculorum* (N.A. Cobb) Dowson, when in 1939 created the genus *Xanthomonas* still valid, with many plant pathogenic species and due to this fact he successfully established the new taxonomic combination for the causal agent of the sugarcane gummosis.

Dowson (1949) wrote the book: Manual of Bacterial Plant Disease, for many years one of the most important texts in plant bacteriology. In that book, the majority of statements related to sugarcane gummosis sintomatology strongly supported Draenert's descriptions of the gummosis symptoms. For instance: in relation to the etiology of the disease Dowson said: *but the most certain diagnostic features is observed on cutting through the stems, the vascular boundless of which will be seen to be red, and exude a copious yellow sticky liquid.* Commenting on disease control he stated: …*The exact manner in which the disease is spread in a plantation is not definitely known. Probably insects are involved but the only ascertained way in which the disease is conveyed from place to place, is by infected cutting from planting with the bacteria already present in these multiply and soon or latter the striping and withering of the leaves follows*. Another Dowson statement that support to Draenert (1869) was related to the influence of the disease in the sugar production: …*the process of disease development is slow and canes showing leaf–strip symptoms are often cut and milled although this yellow gum tends to clog the mills and the liquid obtained is low in sugar content* .

Apparently, Dowson was not aware about Draenert's paper because it was not mentioned in his book, but he presented a map showing the world distribution of sugarcane gummosis and the Northeast of Brazil pointed out as focus of the disease (Figure 3).

The world and specially the North American phytopathological literature indicates Thomas J. Burrill (Figure 4) as the first scientist to report a plant bacteria disease in the world (Walker, 1959), considering his two publication in 1877;1878, under the title: On blight of pear and apple, issued by The Transaction of the Illinois State Horticulture Society. This disease is also known as fire–blight or blossom–blight of pear and twig–blight of apple, affecting pear, apple and quince. The disease is very destructive on pear and to a lesser extent on apple and quince. Large number of species of the Rosaceae family including those cultivated and wilds are susceptible to the disease. Burrill was a great scientist and considered by biographers as one of the most brilliant plant pathologist living in the United States. He worked as a

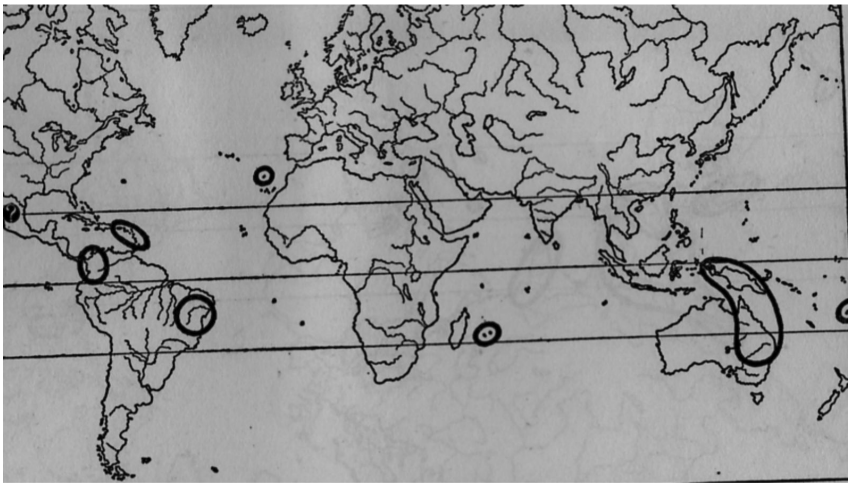

Figure 3. — Worldwide distribution of sugarcane gummosis indicating the presence of the disease in the Northeast Brazil. (Original from W. J. Dowson, 1949)

professor of botany at the University of Illinois having several administrative duties at the same time. He gave a great deal of his scientific attention to the pear–blight and apple–twig disease because both were, (and continue to be) two important phytopathological problems in the U.S., especially in the State of Illinois.

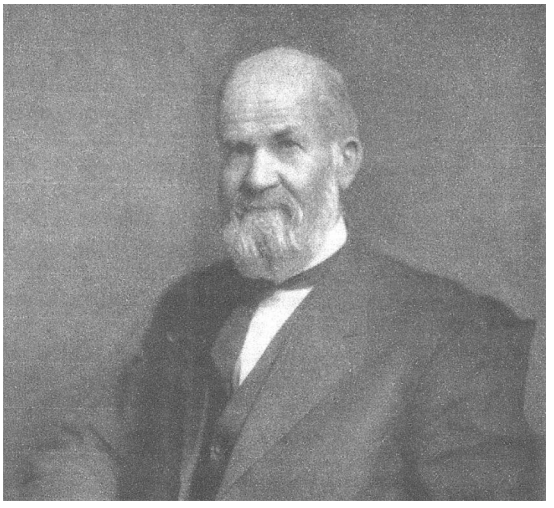

Figure 4. — Thomas Jonathan Burrill (1839–1916) born in Pittsfield Massachusetts, USA, lived in Illinois. He is referred by the international phytopathological literature as the first to describe a plant bacteria disease in the world (Courtesy of D. E. Ellis).

At the beginning of his investigations, Burrill, in 1877, observed under the microscope that an organism was present in drops of the exudates from infected tissues of diseased plants and wrote: …*the field* (of the microscope) *is seen to be alive with moving atoms known in a general way as bacteria.... a particle of this viscous fluids introduced in a health plant upon the point of a knife in many cases was followed by a blight of the part. He added: "Does it not seem plausible that they cause the subsequently apparent change? It does to me, but this is the extent of my own faith; we should not say the conclusion is reached and the cause the disease definitely ascertained. So far as I know, the idea is an entirely new one that bacteria cause diseases in plants though abundantly proved in the case of animal.*

In 1880, a severe outbreak of the blight occurred in the State of Illinois and Burrill with the objective of confirming the cause of the disease, set up several cross inoculation experiments using pear, apple and quince trees. The inoculum used was either exudates or pieces of bark from infected twigs. He collected the exudates in the morning, making sure it was from new lesions only. He then diluted it with a little distilled water and examined it under the microscope to see if it was free from fungi structures coming from the cankers. As the results of his tests high percentages of infection occurred with most inoculated trees dying from the blight.

Burrill's investigations on the etiology of pear blight were confirmed five years later by J. C. Arthur (1885) working at the Geneva, New York Experimental Station, using the poured–plate technique developed by Koch in a well controlled inoculation experiment (in 1882, Robert Koch announced the poured–plate method of isolating bacteria by the use of gelatin as a liquefiable solid medium, which was a great improvement over the dilution culture method used by Louis Pasteur). He isolated the organism in pure culture and using the newly developed plate culture technique, fully demonstrated the pathogenicity of the bacteria. This very infectious plant bacteria species was described taxonomically, before Arthur's paper, by Burril as *Micrococcus amylovorus* Burrill, in his publication Burrill (1883). After three synonymies, actually, the scientific name of this species is *Erwinia amylovora* (Burrill) Winslow et al. Arthr's paper was an scientific classic and the author presented his results as a PhD thesis at Cornell University, 1886, and this is recorded as the first PhD degree conferred in the field of science in that institution. Working in Indiana, Arthur (1886) published the descriptive article: History and biology of pear blight.

An important statement was presented by Kennedy *et al.* (1979): …*Burrill was aware of the work by Mitscherlich (1850) and upon analysis he translated the German noun Vibrionen to mean living atoms. Had Burrill translated the term Vibrionen to mean motile*

bacteria of the genus Vibrio it is possible that Mitscherlich would have become more prominently recognized by plant pathologists.

Burrill had a scientific life limited by many administrative duties. In spite of this, he was outstanding as a scientist. About this matter, Smith (1916) in Burrill's obituary commented: …*I deplore the established practice of promoting brilliant investigators to administrative duties. This I call extinction by promotion and stated: In no way was Burrill rendered totally extinct, but no doubt if he had been free from the administrative burdens his contributions would have been far greater.* Among others, the biographical articles on Burrill by Smith (1916) and Barrett (1918) should be pointed out as excellent.

Erwin F. Smith (Figure 5) the most famous plant bacteriologist in the History of Plant Pathology, strongly supported Burrill's papers and consequently, since than, almost all text books on Plant Pathology and Plant Bacteriology have given credit to Burrill's discovery and pointed him as the first to report a plant disease caused by a bacteria. In their comments, Kennedy *et al.*, 1979, said: …*The influence of Smith apparently was so great that his evaluation and statements about Burrill were uncritically accepted by the authors of most textbooks.*

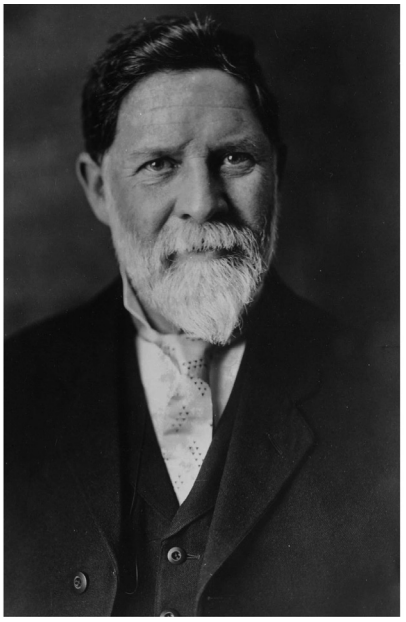

Figure 5. — Erwin Frink Smith (1854–1927), born in New York, USA, was acclaimed "The Father of Plant Bacteriology". His strong support to Burrill's papers was definitive for the indication of that investigator to receive the necessary credit to be the first to report a plant disease caused by bacteria (Courtesy of Marvin D. Whitehead).

In 1893 Smith began his studies on plant bacterial diseases and by 1895 several important papers had been published by him and in 1896, he wrote: Bacterial Diseases of Plants: a Critical Review of the Present State of our Knowledge, in the periodical American Nature (Smith, 1896).

Unfortunately his papers together with all the other North Americans on plant bacteria diseases did not received any credit from the Europeans scientists relying, as it was said, upon the earlier opinion of the A.de Bary who believed that bacteria did not cause disease in plants. In fact, de Bary regarded bacteria as of minor importance as pathogens of plants, proved in his well known statement …*saprofitic bacteria may under special conditions attack tissues of living plants as facultative parasites, producing disease in them and destroy them. But this only confirms what was said above, that bacteria are not objects of great importance as contagia or diseases affecting plants*. Anton de Bary was in that time one the most prominent scientist in Europe working with microbiology and specially with plant diseases. Alfred Fischer, a well recognized German botanist and chemist and former de Bary's student in 1881, belonged to that school of thinking. He criticized Smith's work with bacteria rather sharply as well as similar works by others Americans, and was known to say quite freely that he had no room on his book shelves for American publications as they contained nothing useful. In his book: Lectures on Bacteria, he wrote in 1897, Fischer denied the reliability of the results of Smith and others Americans who claimed to have seen bacteria in plant cells. Smith undertook the defense of his work and the work of his fellow countrymen. In Smith (1889a) he strongly replied Fischer pointing out his complete lack of sound knowledge of the subject. Fischer replied him in the same year and Smith (1899 b) replied Fischer again. These rebuttal papers: were: Are there bacteria disease of plants? and Dr. Alfred Fischer in the role of pathologist seemed to end the controversy (Walker, 1957). Dr. Alfred Fischer was a active professor of botany in the *Königlichen Gymnasium* at Leipzig, German. After all, it may be said that it was a strong and unpleased controversy that later became an important historical event. During the struggle, Smith fluent in German wrote papers in European periodicals, especially Germanics, even in those periodicals used by Fisher (Smith, 1901). As the result, Smith became victorious and received the acceptance by the most European biologists. Evidently, there remained some few unconvinced scientists, but history had been made and bacterial–plant pathology was well on its way. According to Smith biographers he enjoyed the endorsement of his scientific discoveries without

exception during that long struggle.

In the years of 1905, 1911 and 1914 Smith published through the Washington D.C. Carnegie Inst. the series: Bacteria in Relation to Plant Diseases, with great acceptance. Later, and successfully, he published the book: An Introduction to Bacterial Diseases of Plants (Smith, 1920).

For his scientific production, his fight for recognition of the field of plant bacteriology, the large number of new bacterial pathogens he found, described and work with and the students he oriented brought to E.F. Smith with all merits the title of "Father of The Plant Bacteriology".

According to his biographies, E. F. Smith was a quite unique person. Besides sciences, he was interested in general literature and languages. He was well known by reading famous works in the original rather than the translations. Dante's works in the original Italian were his favorites. He read the scriptures in Latin, Goethe in German; rejoiced in the music of Beethoven and wrote considerable amount of poetry, some of which published in his book: For Her Friends and Mine, a biography of his first wife.

On March 8, 1927, Prof. Smith, the way he used to be call, suffered a heart attack and from then until his death on April 6 of the same year he was never in good health, although he went to his laboratory almost every day, for the three weeks following the initial attack. His passing was a great loss to the field of plant pathology and plant bacteriology, a new science that was borne in his time, under his great influence. He will remain in history as one of the main founders and key contributors to those important sciences for mankind (Jones, 1939).

Dedicatory

This article is dedicated to Prof. Don E. Ellis, in memoriam. He was the professor of History of Plant Pathology (PP 608) in the Department of Plant Pathology, in the North Carolina State University in the seventies, when I was his student. His excellent lectures, useful class outlines and topic discussions will never be forgotten for his former students. Friendlily, he frequently stated: Those who ignore history are condemned to repeat it.

Bibliographic References

ARTHUR, J.C. Proof that bacterial are the direct cause of the disease in trees known as pear blight. Botanic. Gaz. 10: 343–345. 1885.

ARTHUR, J.C. History and biology of pear blight. Proc. Phil. Acad. Natl. Sci. 322–341. 1886.

BARRETT, J.T. Thomas Jonathan Burrill. Phytopathology 8: 1–4. 1918.

BURRILL, T.J. 1877–1878. Pear blight. Trans. Ill. State Hort. Soc. (1877: 114–116); (1878: 79–80).

BURRILL, T.J. New species of *Micrococcus* (bacteria) Am. Nat 17: 319. 1883.

CAMINHA FILHO, A. Doenças da canna de assucar no Brasil. 1936. In: Moura, R.M. (Org.) Annaes da Primeira Reunião de Phytopathologistas do Brasil. Rodriguésia, Número Especial. Republicado pela Soc. Bras. Fitopatol, Brasília D.F., 245–250. 2006.

COSTA, A.S. História da Fitopatologia no Brasil. Summa Phutopathologica 1: 155–166. 1975.

DANTAS, B. Contribuição para história da gomose da cana–de–açúcar em Pernambuco e no Brasil. Bol. Tec. Inst. Agron. Nordeste 11: 3–17. 1970.

DOWSON, W.J. Manual of bacterial plant diseases. New York. The Mac Millian Company. 1949.

DRAENERT, F.M. Weitere notizen über krankheit des zuckerrohrs. Zeitschrift für Parasitenkunde, Jena, Germany. 1869a. (not consulted).

DRAENERT, F.M. Molestia da canna de assucar na Bahia. Salvador. Jornal da Bahia. n.4935, p.1. 1879b.

DRAENERT, F.M. Molestia da canna de assucar na Bahia. 1879c. In: Moura, R.M., Menezes, M. & Mariano, R.L.R. (Eds). Anais da Academia Pernambucana de Ciência Agronômica 3:327–231. 2006.

JONES, L.R. Biographical memoir of Erwin F. Smith. Nat. Acad. Sci. Biogr. 21. 1939.

KENNEDY, B.W., WIDIN, K.D. & BAKER, I.S.F. Bacteria as the cause of disease in plants: a historical perspective. ASM News 45:1–5. 1979.

MITSCHERLICH, E. Sitzung der physikalischmathematischen Klasse. Monatsschr. Kais. Akad. Wiss. Berlin 102–110. 1850.

PUTTEMANS, A. Alguns dados para servir á história da Phytopathologia no Brasil e as primeiras notificações de doenças vegetais neste paíz. (1936). In: MOURA, R.M. (Org.) Annaes da Primeira Reunião de Phytopathologistas do Brasil. Rodriguésia, Número Especial. Republicado pela Soc. Bras. Fitopatol., Brasília D.F. 37–60. 2006.

SMITH, E.F. The bacterial disease of plants a critical review of the present state of our knowledge. Am. Nat. 30:626–643. 1896.

SMITH, E.F. Are there bacterial diseases of plants? Ibid. 5:271–278. 1899a.

SMITH, E.F. Dr. Alfred Fischer in the role of pathologist. Ibid. 5:810–817. 1899b.

SMITH, E.F. Entegegnung auf Alfred Fisher's "Antwort" in Betreff der Existenz von durch Bakterien verursachten Pflanzenkrankheiten. Ibid. 7:88–100, 128–139, 190–199. 1901.

SMITH, E.F. In memoriam of Thomas J. Burrill. Jour. Bact. 1: 269–271. 1916.

THIMANN, K.V. The life of bacteria. New York. The MacMillian Co. 1963.

TOKESHI, H. & RAGO, A. Doenças da cana–de–açúcar. In: Kimati, H, Amorim, L., Resende, J.A.M., Bergamin Filho, A. & Camargo, L.E.A. (Eds.) Manual de fitopatologia. v.2. Doenças das plantas cultivadas. São Paulo. Ed. Agro. CERES LTDA. 2005. pp.185–196.

WALKER, J.C. Plant pathology. New York. McGraw Hill Book Company. 1957.